International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 4, Aug 2019, 1245–1254

FREE VIBRATION CHARACTERISTICS OF ALKALI TREATED UNIDIRECTIONAL LONG KENAF FIBER REINFORCED EPOXY COMPOSITES AT VARIOUS END CONDITIONS

T VENKATEGOWDA[1] & MANJUNATHA LH[2]

[1]Department of Mechanical Engineering, Maharaja Institute of Technology, Thandavapura, Mysuru, Karnataka, India

[2]Department of Mechanical Engineering, REVA University, Bangalore, Karnataka, India

ABSTRACT

Composite materials are extensively used in many diverse applications such as aircraft strictures, sporting goods, packaging goods, construction and automobile components. Since noise and vibration is common phenomena in the working life, determination of natural frequencies and internal damping of the developed composite materials are in high practical demand, in order to observe the vibration behaviour when they are subjected to periodic exciting forces. The natural frequencies of a system are a function of its mass and elastic properties. Internal damping results from Mechanical energy dissipation within the material due to viscous microscopic and macroscopic processes. Damping capacity and natural frequency are the fundamental properties for designing the components. Damping is one of the significant factors for the fatigue life and impact resistance. Significant improvements have been made towards predicting the vibration behaviour of composite materials for various end conditions. This presents free vibration behaviour of long Kenaf fiber reinforced epoxy composites. The effect of fiber content on the damping and natural frequencies were studied in this investigation. Generally, damping present in the fiber reinforced composite material is more than the metallic material due to its visco-elastic behaviour and fiber matrix interaction. Damping measures rate at which vibration dissipates. In order to improve the mechanical properties, alkali treatment has been done. The vibration test is carried out using National instruments USB 4431 five channel data acquisition module, Endevco 256 small piezoelectric accelerometer and Endevco 2301 impact hammer for different end conditions. The Vibrant technology, ME Scope software is used to convert responses from time domain to frequency domain. Hand lay-up technique is used to prepare the composite plate.

KEYWORDS: Kenaf Fibre, Epoxy, Vibration, Damping & Experimental Modal Analysis

Received: Jun 01, 2019; **Accepted:** Jun 21, 2019; **Published:** Jul 29, 2019; **Paper Id.:** IJMPERDAUG2019129

Original Article

INTRODUCTION

Many composite materials composed of only two phases; one is termed as matrix phase which is continuous and surrounds the other phase, often called reinforcement phase. Reinforcement materials are strong with light weight, whereas, matrix usually tough or ductile material. If the matrix is designed and fabricated properly, it combines the strength of the reinforcement with the toughness of the matrix material to obtain a combination of superior properties, which are not available in any single conventional material. Fiber reinforced polymer composites consists of high strength fibres (reinforcement) embedded in polymer matrix. The fiber, which acts as a reinforcement in polymer may be synthetic or natural. In the recent decades, environmental awareness and depletion of petroleum resources motivates the number researchers and scientists worldwide, on the studies of natural fiber reinforced composites. The availability, biodegrability,

renewability of inexpensive natural fibres and ease of manufacturing has tempted many researchers on development of low cost light weight composite material. Natural fibres do not pose any serious health hazards while processing them.

In the recent years, various industries have shown the interest to reduce the use of synthetic fibres and to increase development of green composites. This leads to the development of natural fiber reinforced polymer matrix composite. Natural fibres have low density, specific strength and high stiffness. Also, natural fibres are relatively cheap compared to synthetic fibres. Because of biodegradable nature of natural reinforced composites, they can easily decompose in the environment. The mechanical properties of the developed natural fiber reinforced composites depends upon many factors such as properties of fibres and polymers, orientation of fibres, bonding strength between fibres and matrix, fibres and matrix content etc. The main disadvantage of using natural fiber is its high level of moisture absorption, insufficient adhesion between the untreated fibres and the polymer matrix which leads to deboning with age.

Vibration is undesirable phenomena in structures due to the need for stability, durability against fatigue, position control, noise reduction and performance. Vibration reduction can be achieved by increasing the damping capacity. Damping is helpful in many cases and limits the amplitude of vibration. Due to the viscoelastic behaviour polymers, polymer composites can provide good damping. Based on the theoretical frequency equation, the natural frequency depends upon the stiffness and mass of the structure. The increment of the mass will reduce the natural frequency of the structure where as an increasing in the stiffness will influence the natural frequency with increased value.

METHODOLOGY

Materials and Specimen Preparation

Long kenaf fibers collected from go green products, Guntur, Andrapradesh, were treated with 6% NaOH (alkali treatment) and have been used as reinforcement. The fibres were subjected to alkali treatment in order to improve the interfacial adhesion between kenaf fiber and epoxy matrix. The epoxy LY-556 is used as matrix, procured from Zenith industrial suppliers, Bangalore, Karnataka, India. HY-951 hardener has been used as catalyst and accelerator for room temperature curing in the ratio of 10:1 as per the manufacturer data. The composite plate consists of 4 plies and each ply consisting of unidirectional long kenaf fiber with epoxy layer. The details of prepared composite plates are shown in the below table:

Table 1: Compositions of Prepared Composite Plate

Plate Nomenclature	Kenaf Fiber (%)	Eopxy (%)
B	90	10
D	80	20
F	70	30
H	60	40

Experimental Setup for Free Vibration Test

Experimental modal analysis is a technique to extract modal parameters such as natural frequency, modal damping and mode shape of a structure. The dynamic properties are evaluated to observe how a structure reacts when it is subjected to external force. The origin of force due to a repeating shock, an unbalance in a rotating structure, and a time varying load. The experimental setup used for modal analysis of long kenaf fiber reinforced epoxy composites using impact hammer is shown in figure 1.

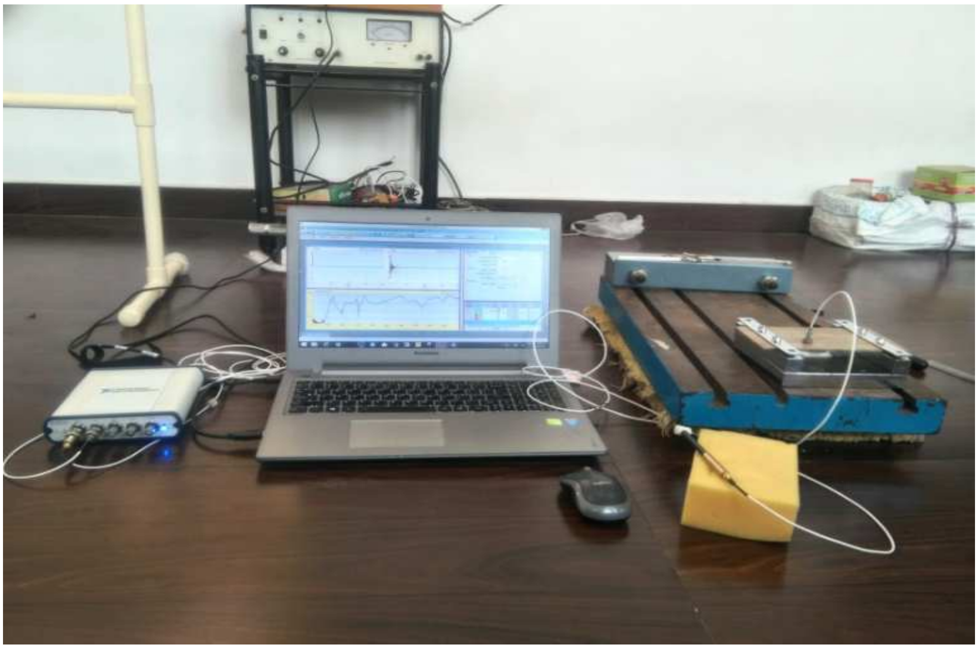


Figure 1: Experimental Setup for Model Analysis

A composite plate having dimension of 180 mm x 90 mm x3 mm was used for the test. The plate is divided into many number of grid points to measure damping and natural frequency. The accelerometer is attached at one of the corner of the rectangular plate using glue and connected to one of the channel of data acquisition system (National Instruments USB 4431) to digitize input signals. In practice, the plate under test excited by impact using a light hammer (Impact hammer) on equally spaced grid points for getting frequencies. The response of the system due to the excitation is measured with accelerometer. The displacement signal is directly recorded to the personal computer through data acquisition system and with the help of software, frequencies are plotted. Test has been carried out for three end conditions.

Figure 2: Data Acquisition Card

Figure 3: Impact Hammer

Figure 4: Accelerometer

Free-Free End Condition

In this process, the plate is divided into 35 grid points as shown in figure 5 to describe global structural mode shape and is attached to platform using a thin wire for the excitation purposes. The uniaxial accelerometer was glued at one

of the grid point of any free end on the surface of the plate. While testing, the beam was excited using impact hammer at the grid points.

Figure 5: Specimen Hanged in the Fixture for Free-Free End Condition

Fixed-Free End Condition (Cantilever Beam)

In this process, the plate is divided into 30 grid points as shown in figure 6 to describe global structural mode shape and is attached to fixture mounted on the work table. The uniaxial accelerometer was glued at one of the grid point of the free end on the surface of the plate. While testing, the beam was excited using impact hammer at the grid points.

Figure 6: Specimen Fixed in the Fixture for Fixed-Free End Condition (Cantilever)

Fixed-Fixed End Condition (Fixed Beam)

In this process, the plate is divided into 25 grid points as shown in figure 7 to describe global structural mode shape and is attached to fixture mounted on the work table. The uniaxial accelerometer was glued at one of the grid point nearer to one of the fixed support on the surface of the plate. While testing, the beam was excited using impact hammer at the grid points.

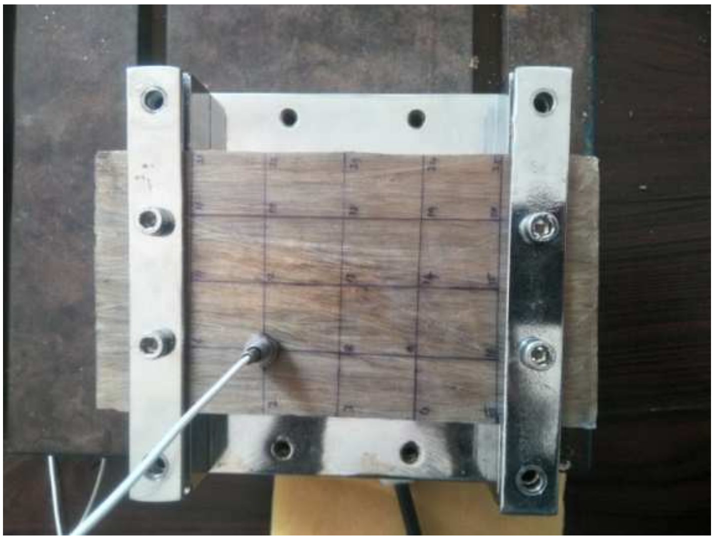


Figure 7: Specimen Fixed in the Fixture for Fixed-Fixed End Condition

RESULTS AND ANALYSIS

The oscillatory motion is a characteristic property of the structure, which depends upon the distribution of mass and stiffness. The oscillatory motion takes place at certain frequencies, known as natural frequencies under external excitation and it follows well defined deformed pattern known as normal shape or mode shape. Free vibration behaviour is very important to observe dynamic response of an elastic structure.

The addition of fiber content to viscoelastic polymer can make a contribution to increase in natural frequency and internal damping. The contribution to the internal damping results from intrinsic damping and boundary sliding of fibres, interfacial sliding between fibres and matrix. Vibrational energy dissipated due to shear forces and viscoelastic behaviour of polymer matrix. Test has been carried out on different plates for different end conditions. The frequency response curve is obtained directly from the software (Vibrant technology ME Scope). The responses measured 10 times at each grid point and average value was used. The first three natural frequencies were measured from experimental modal analysis. From the experimental results, it is observed that natural frequency and damping increases if the fiber content increases. The increase in natural frequency is due to the increased kenaf fiber reinforcement in the matrix results in improved stiffness. The following table shows first three natural frequencies investigated experimentally under varying fiber content with epoxy. The following tables show the vibration characteristics of different composite plates for various end conditions.

Table 2: Natural Frequency, Damping and Damping Ratios for Free-Free End Condition

Sample	End Condition	Mode	Frequency (f_n) 'Hz'	Damping	Damping Ratio 'ζ'
B	Free-Free	1	201.3	1.6817	0.83539
		2	301.13	2.0483	0.6802
		3	504.22	4.6826	0.92863
D		1	204.82	2.0385	0.99522
		2	337.25	2.6138	0.775
		3	510.53	5.5503	1.0871
F		1	200.59	2.306	1.1495
		2	399.63	2.663	0.66635
		3	525.83	8.0922	1.5387
H		1	218.21	2.8006	1.2833
		2	419.78	3.6192	0.86212
		3	556.01	11.619	2.0893

Table 3: Normal Shapes for Free-Free End Condition

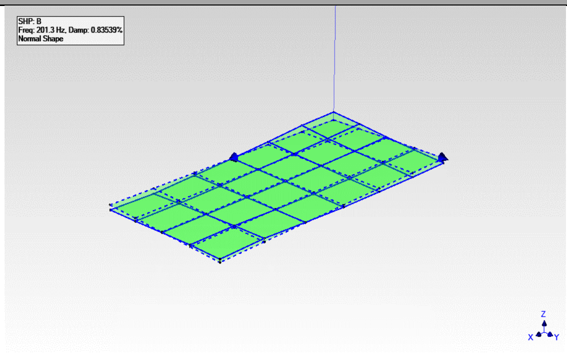
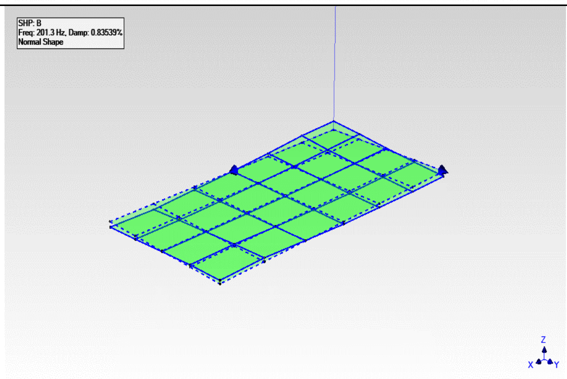
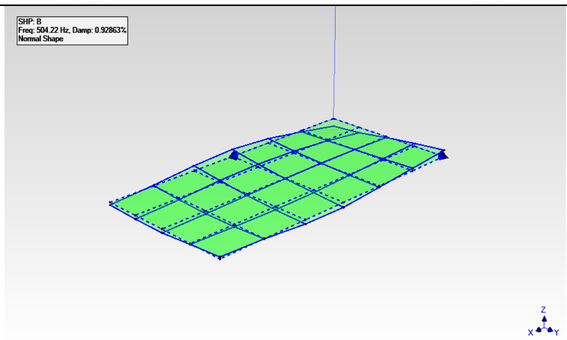
End Condition	Mode Shape or Normal Shape	Mode Number	Description of Mode Shape
Free-Free		1	Twisting
		2	Bending
		3	Twisting

Table 4: Natural Frequency, Damping and Damping Ratios for Fixed-Free End Condition

Sample	End Condition	Mode	Frequency (f_n) 'Hz'.	Damping	Damping Ratio 'ζ'
B	Fixed-Free	1	55.718	0.41343	0.74198
		2	135.07	2.0479	1.516
		3	376.02	3.9943	1.0622
D		1	63.748	0.50871	0.79797
		2	142.13	2.3249	1.6355
		3	414.02	6.0177	1.4533
F		1	76.626	1.2372	1.6143
		2	143.28	2.2407	1.5636
		3	468.06	6.1795	1.3201
H		1	82.842	0.98263	1.1861
		2	158.29	3.4346	2.1693
		3	516.55	3.0577	0.59194

Table 5: Normal Shapes for Fixed-Free End Condition

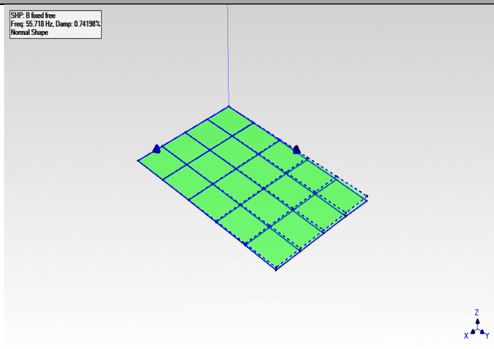
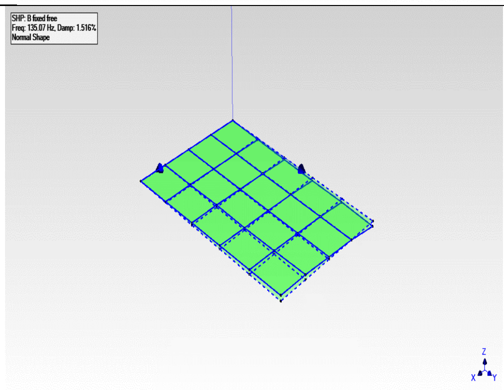
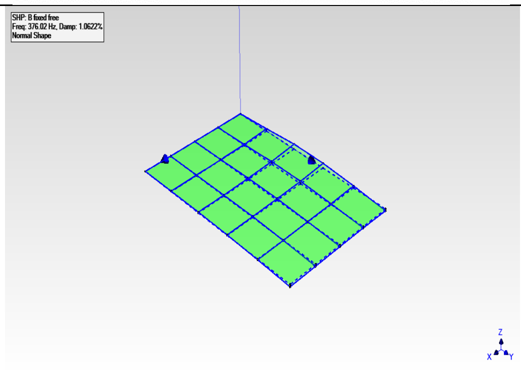
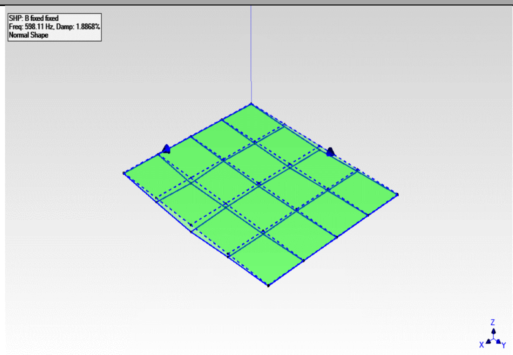
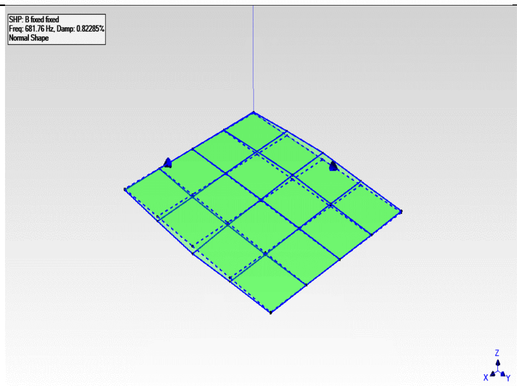
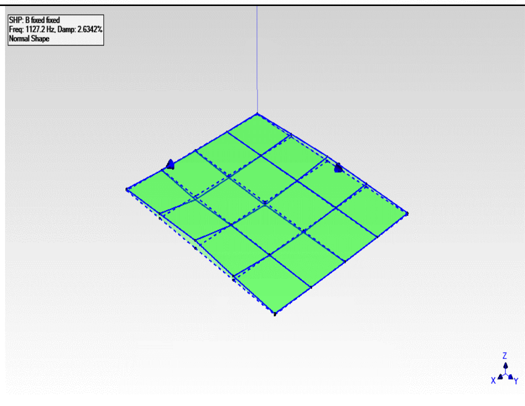
End Condition	Mode Shape or Normal Shape	Mode Number	Description Of Mode Shape
Fixed-Free		1	Bending
		2	Twisting
		3	Twisting

Table 6: Natural Frequency, Damping and Damping Ratios for Fixed-Fixed End Condition

Sample	End Condition	Mode	Frequency (f_n) 'Hz'.	Damping	Damping Ratio 'ζ'
B	Fixed-Fixed	1	598.11	11.287	1.8868
		2	681.76	5.6101	0.82285
		3	1127.2	29.702	2.6342
D		1	724.68	17.665	2.4368
		2	777.68	6.4259	0.82626
		3	1171	35.744	3.051
F		1	779.21	12.601	1.617
		2	1793.5	56.284	3.1367
		3	--------	---------	---------
H		1	726.79	11.973	1.6472
		2	967.35	12.318	1.2733
		3	1234	40.219	3.2577

Table 7: Normal Shapes for Fixed-Fixed End Condition

End Condition	Mode Shape or Normal Shape	Mode Number	Description of Mode Shape
Fixed-Fixed		1	Bending
		2	Twisting
		3	Twisting

CONCLUSIONS

The experiment modal analysis technique was employed to evaluate natural frequency and damping of unidirectional long kenaf fiber reinforced epoxy composites. The first three natural frequencies were obtained. Fiber content of developed composite played an important role in the vibration characteristics. The addition of kenaf fiber reinforcement to epoxy matrix makes a contribution to increase natural frequency and damping effect. Composite with higher fiber volume is much stiffer than composite with lower fiber volume. Among B, D, F, H, H has higher frequencies and has good damping than B, D and F. So, H can be used for structural and high stiffness applications. Finally, the results suggest that it can be possible to obtain a desired damping and vibration capability by varying the content of kenaf fibres.

REFERENCES

1. *NVijayasai, PNandaKishore, CHPremKumar (2014). Investigationon Dynamic Behaviour of Hybrid Sisal-Bagasse Fabric Reinforced Epoxy Composites, International Journal of Innovative Research in Advanced Engineering, Vol. 1, pp. 357–360*
2. *K. T. B Padal, K. Ramji, VVS Prasad (2014). Damping Behaviour of Jute Nano Fibre Reinforced Composites, International Journal of Emerging Technology and Advanced Engineering, Vol.4, pp. 753–759.*
3. *Alaa Abdulzahra (2016). Experimental and Numerical Investigation of Date Palm Fiber Effect on Natural Frequency of Composite Plate with Different B.Cs," International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, pp. 1163-1174.*
4. *Patil Abhijeet Sunilkummar, K V Manoj, Hudagi Shripad Basavraj, G. Venkatachalam (2016). Vibrational Behaviour of Sandwich plate with Core as Jute Reinforced Polymer Matrix Composites, International Journal of Advances in Engineering Research, Vol. 11, pp. 120–126.*
5. *Reddy, A. C. (2015). Studies on loading, cracking and clustering of particulates on the strength and stiffness of 7020/SiCp metal matrix composites. International Journal of Metallurgical & Materials Science and Engineering, 5(1), 53–66.*
6. *S Prakash, R Christupaul (2016). Experimental Investigation of Natural Fiber Reinforced Polymer Composite, International Journal of Advanced Engineering Technology, Vol.7, pp. 937–941.*
7. *Arulmurugan S, and Venkateshwaran N (2016). Vibration Analysis of Nano clay Filled Natural Fiber Composites, Polymers & Polymer Composites, Vol. 24, pp. 507–516.*
8. *Dr. P. S. Senthil Kumar, Karthik. K, Raja. T (2015). Vibration Damping Characteristics of Hybrid Polymer Matrix Composites, International Journal of Mechanical & Mechatronics Engineering, Vol.15, pp. 42–47.*
9. *K. L. NareshRaj, K. G. Ashok. (2016). Design and Fabrication of Vibration Damping Padusing Luffa Cylindrical Fibre Reinforced Polymer Composite, International Journal of Multidisciplinary, Research and Modern Education, Vol.2, pp. 441–448.*
10. *Ömer Yavuz Bozkurt, MehmetBulut, Özkan Özbek (2016). Effect of Fibre Orientations on Damping and Vibration Characteristics, Proceedings of the World Congresson Civil, Structural, and Environmental Engineering (CSEE'16), pp. 115.1–115. 6.*
11. *P. Ganesa and S. Thirumavalavan (2014). Free Vibration Behaviour of Glass Fiber Reinforced Polymer Composite, Middle-East Journal of Scientific Research, Vol. 20 (6), pp. 734–737.*
12. *Reddy, A. C. Low And High Temperature Micromechanical Behavior of Bn/3003 Aluminum Alloy Nanocomposites.*
13. *N. Abilash, M. Sivapragash (2013). Testing the Vibrational Behaviour of Jute Fiber based Sandwich Composite, An International Journal of Engineering Science and Technology, pp. 130–137, Vol.3.*
14. *Zheng Wang, LinkLi, Meng Gong (2012). Measurement of Dynamic Modulus of Elasticity and Damping Ratio of Wood-based Composite using the Cantilever Beam Vibration Technique, Journal of construction and building materials, Vol. 28, pp. 831–834.*
15. *AkashD. A, Thyagaraj. N. R, Sudev. L. J (20130. Experimental Study of Dynamic Behaviour of Hybrid Jute/Sisal Fibre Reinforced Polyester Composite, International Journal of Science and Engineering Applications, Vol.2, pp. 2319–7560.*
16. *J. Alexander and B. S. M. Augustine (2015). Free Vibration and Damping Characteristics of GFRP and BFRP Laminated Composites at Various Boundary Conditions, Indian Journal of Science and Technology,Vol.8 (12), PP.1–7.*
17. *Rohitraman, upasanasaikia (2017). Study of Mechanical Behaviour of Composite Materials by Vibration Analysis, International Journal of Advanced Research, Ideas and Innovations in Technology, Vol. 3, pp. 831–836.*

18. *N. Nayak, S. Meher, S. K Sahu (2013). Experimental and Numerical Study on Vibration and Buckling Characteristics of Glass-Carbon/Epoxy Hybrid Composite Plates, Proceedings of International Conference on in Advances Civil Engineering, Elsevier, pp. 888–895.*
19. *Patel, J. K., & Das, A. M. A. R. E. S. H. (2015). Assessing toxic metals contamination in soil, water and plant bodies around an industrial belt. Int J Res Appl Nat Soc Sci, 3(2), 5–20.*
20. *Devidas R Patil, P. G. Damle, D. S. Deshmukh (2014). Vibration Analysis of Composite Plate at Different Boundary Conditions, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, pp. 18089–18094.*
21. *M. L Pavan Kishore, R K Behera, D Harsha Vardhan (2014). Free Vibration Analysis of Four Bladed Propeller using Different Materials, Proceedings of 4th SARC International Conference, pp. 88–91.*
22. *Sridhar I, Venkatesha C S (2013). Variation of damping property of Polymer Composite under Saline Water Treatment, International Journal of Innovations in Engineering and Technology, Vol. 2, pp. 420–423.*
23. *S. S. Chavan, M. M Joshi (2015). Study on Vibration Analysis of Composite Plate, International Journal of Advances in Production and Mechanical Engineering, Vol. 1, pp. 69–76.*